

## **IV. CONCLUSIONS AND RECOMMENDATIONS**

### **A. CONCLUSIONS**

In this research, the effect of geometric hull parameters, such as the length, the diameter and the shape factors of the hull, on the vertical plane response of submersible vehicles in the proximity of a free surface in deep water have been evaluated. Two cases, namely limited diameter and limited length, are considered, where in the first case overall length and in the second case the diameter is kept constant. The responses are evaluated by using a potential flow, strip theory solver for each case and for certain shape factors and different speed/operating depth combinations. Periscope submergence, sail broaching and the combination of both criteria are considered, in order to plot the operability envelope of the vehicle for different sea states and sea directions, using the above parameters. An operability index is calculated to quantify the operability of the vehicle. The main conclusions which are drawn from the study are shown below:

1. For the periscope submergence criterion, regardless of the variation of the parameters, head seas appear to result in a larger number of expected criterion violations than the following seas. Changes in the shape factors appear to have greater effects at smaller speeds and larger depths. An optimum shape factor for a certain operating depth, which minimizes the expected number of periscope submergence events can be found, and this appears to be a weak function of speed. Since the shapes of the operability envelopes can be quite different, similar values of the operability index may result in very different response characteristics.
2. For the sail broaching criterion, smaller shape factors generally yield smaller indexes. The operability index tends to increase as the depth increases, and in general, it is a

weak function of speed for all shape factors. The operability index does not appear to depend on sea direction consistently. At certain directions, the index decreases significantly for various shape factors and speed/depth combinations.

3. For the combined criterion, at smaller operating depths, changing the shape factors appears to yield a slight change in the number of expected criterion violations. At higher depths, smaller shape factors result in smaller operability indexes. Velocity has a little effect on the operability indexes at smaller operating depths. As the depth increases, the indexes appear to decrease with increasing speed.

## **B. RECOMENDATIONS**

For further research on near surface response of submersible vehicles, the following studies are recommended:

1. In higher sea states for periscope submergence, even though the criterion is not violated, the average wave height may exceed the exposed periscope length, since the motion point appears to move more in phase with the incoming waves at higher sea states. This may cause difficulties in the operations, because the periscope moves in phase with the waves and the operator's visual horizon may be very small. Such situations should be analyzed with proper simulation studies.
2. Evaluating the effects of second order wave forces and motions on vehicle response. Even though these motions are slowly varying and can be controlled to a certain extent, they may alter both the values of the operability indices and the shape of the corresponding polar plots.

